Evaluating Selected Protectants for Shelled Corn Against Stored-Grain Insects

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U.S. DEPARTMENT OF AGRICULTURE

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Evaluating Selected Protectants for Shelled Corn Against Stored-Grain Insects

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ABSTRACT

Protectant insecticides were tested on shelled corn in small bins. Of the candidates sprays, pirimiphos-methyl and chlorpyrifos-methyl were superior to the standard dosage of malathion in protecting the corn against attack by stored-grain insects. Fenitrothion rendered protection equal to malathion.

A malathion and diatomaceous-earth dust gave the best protection, but the addition of the dust reduced the test weight of the corn.

Key words: Insecticides, pirimiphos-methyl, chlorpyrifos-methyl, corn, stored-grain insects, fenitrothion, malathion, and diatomaceous earth.

SUMMARY

Candidate insecticides were tested as protectants to shelled corn stored in small bins. Damaging infestations of mixed populations of stored-grain insects were readily established in all bins of untreated corn. At the dosages applied, pirimiphos-methyl (*0*-[2-(diethylamino)-6-methyl-4-pyrimidinyl] *0,0*-dimethyl phosphorothioate) and chlorpyrifos-methyl (*0,0*-dimethyl *0*-[3,5,6-trichloro-2-pyridyl] phosphorothioate) were superior to the standard dosage of malathion as protectants on corn against attack by stored-grain insects. Fenitrothion (*0,0*-dimethyl *0*-[4-nitro-*m*-tolyl] phosphorothioate) rendered protection equal to malathion.

The malathion-diatomaceous earth dust (M+K) formulation gave the best protection to the corn under test, but the addition of the dust (Kenite 2-I) lowered the test weight about 3 pounds per bushel. The M+K dust was the only material to provide satisfactory long-term protection against lesser grain borer attack. Malathion residue degraded more slowly on corn treated with the dust formulation than when applied as an emulsion. The dust formulation repelled rice weevil adults in free-choice selection and repellency studies; but none of the other treatments affected the attractiveness or repellency of the treated corn.

Pirimiphos-methyl residues degraded relatively slowly as 38.0 percent of the initial deposit remained on the corn after 12 months' storage in comparison to 23.0 percent for chlorpyrifos-methyl, 12.9 percent for fenitrothion, 15.6 percent for malathion from the spray application, and 39.0 percent for malathion from the dust application.

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BACKGROUND AND OBJECTIVES

This storage study compared the effectiveness of pirimiphos-methyl, fenitrothion, chlorpyrifos-methyl, and a M+K dust with the standard recommended application of malathion as protectants of shelled corn against insect attack.

In general, three phases of testing are required to develop a protective treatment for grain: (1) preliminary laboratory evaluations of insecticides, (2) a small-bin evaluation, and (3) full-scale bin, elevator, and warehouse tests. The most promising materials and their dosages are selected from the laboratory studies for testing dosage rates, residue degradation, and efficacy in small-bin storage tests. The .14 m^3 (5 ft^3) small cylindrical bins have been extensively used in intermediate-type storage studies with wheat, rice, almonds, sorghum grain, and corn. Considerable money and time are saved by the early elimination of ineffective materials and dosages found in intermediate tests.

In this test, dosages selected from laboratory studies of the protectants were applied to the corn.

MATERIALS AND METHODS

Shelled yellow corn that had been stored in an elevator bin from harvest until December was processed through a Clipper cleaner to size the kernels and remove most of the foreign material and broken kernels. The moisture content averaged 13.6 percent before cleaning.

Malathion, the standard treatment for comparison, was applied as a water emulsion spray prepared from premium grade 57 percent malathion emulsifiable concentrate (EC), 0.6 kg/liter (5 lb active ingredient (AI)/gal) at 473.1 ml (1 pint) EC/1,000 bu (11.2 p/m). All emulsions were applied with an ultra low-volume atomizing spray assembly (LaHue 1969)[2] modified with high-volume fluid and air nozzles that delivered 18.9 liters (5 gal) finished spray/1,000 bu. Pirimiphos-methyl EC, 0.6 kg/liter (5 lb AI/gal) was applied at the rate of 335 ml (0.75 pint) /1,000 bu (8.4 p/m), chlorpyrifos-methyl EC, 0.24 kg/liter (2 lb AI/gal) at 709.7 ml (1.5 pint) /1,000 bu (6.7 p/m), and fenitrothion EC, 0.96 kg/liter (8 lb AI/gal) at 236 ml (0.5 pint) /1,000 bu (8.9 p/m). Also M+K dust was formulated for an application of 473 ml (1 pint) malathion EC in 27.2 kg (60 lb) of a diatomaceous earth (Kenite 2-I) /1,000 bu corn (11.2 p/m malathion).

All spray materials were applied to 2 bu of corn in 208.2-liter (55 gal) steel mixing barrels fitted with diagonal mixing bars that rotated at 16 r/m for 10 minutes on an electric barrel roller. The dust was added to the corn as 2 bu were placed in a mixing barrel. Immediately after two such lots were treated, the 4 bu of treated corn was placed in 0.14 m^3 (5 ft^3) uncovered fiber drums for storage. After all bins were filled to within 5 cm (2 in) below the top, the surface of the grain was leveled so that each bin had an equal area available for insect entry. There were four replications of each treatment with four (untreated corn) check bins. The bins were stored in a 5.2 × 6.7-meter (17 × 22 ft) room maintained at 26.4 ± 1° C and 60 ± 5 percent RH. Treatments were placed in bins in a selective randomized arrangement to uniformly distribute each treatment in four widely separated areas of the storage room.

Immediately after the corn was cleaned and before it was treated, samples were taken to determine the uniformity and extent of insect damage. The treated corn was held in storage for 12 months.

Major insect releases, each of about 5,000 rice weevils, *Sitophilus oryzae* (L.); 3,000 confused flour beetles, *Tribolium confusum* Jacquelin duVal; and 3,000 red flour beetles, *T. castaneum* (Herbst), were made in the storage room 21, 45, 90, 135, 180, and 260 days after the experiment was started. Jar cultures of flat grain beetles, *Cryptolestes pusillus* (Schönherr),

[2]LaHue, D. W. Evaluation of several formulations of malathion as a protectant of grain sorghum against insects . . . in small bins. U.S. Dept. Agr., Market. Res. Rpt. No. 828. 19 pp. 1969.

and saw-toothed grain beetles, *Oryzaephilus surinamensis* (L.), were maintained in the storage room from the third month until the test was terminated.

Temperatures were taken with mercury thermometers from near the center of the grain mass in each bin at weekly intervals after treatment.

SAMPLING

For detailed studies, samples were taken from each bin with a nonpartitioned grain probe after 4, 8, and 12 months' storage. The probe was inserted vertically near the center and about 6 cm from the bin wall in each of the four quadrants until about 3,000 grams were taken from each bin. Probings were also made for residue samples and other studies as required.

The samples were sifted on a rotary sifter, and the insects were counted to estimate the population in each bin. The fine dusts from the M+K samples were immediately separated from the screenings and returned to the parent sample. The parent samples were then mixed for 15 minutes on a wheel mixer before determining the test weight, moisture content, and use in bioassay, food selection, and repellency studies.

All subsamples used in the toxicity, food preference, and repellency studies were held in a deep freeze at −30° C for 168 hours before insect exposures to eliminate any insect emergence because of a self-contained infestation. Before testing, these samples were held at 26° C and 60 percent RH for 48 hours following removal from the deep freeze to allow for moisture and temperature equation.

The 200-gram subsamples were placed in 473-ml screen-covered glass jars for toxicity tests. Groups of about 50 adult rice weevils, red flour beetles, confused flour beetles, and lesser grain borers *Rhyzopertha dominica* (F.) each were placed in separate jars. Mortality counts were made 21 days later and the live and dead insects were discarded. All fine dusts removed from the samples during the screenings made for the mortality counts were returned to the respective jars. After the mortality counts were made, the samples were held for the emergence of F_1 progeny. Following the progeny counts, all samples were retained for an additional time for a visual assessment of the developing infestations, if any were established.

For the test of the acceptance or avoidance of the corn treated by the different formulations, about 250 rice weevils were released in multichoice food preference or selection chambers. In each of these chambers, 237-ml (½-pint) cardboard cartons, each filled with corn from one of the different treatments and from the untreated check, were exposed to the dispersal of about 250 rice weevils released in the center depression. The rice weevils were allowed 24 hours to enter and remain in or leave the cartons of grain. The weevils were sifted from the grain for counting.

Repellency tests were conducted with replicated samples from all bins 1, 4, 8, and 12 months after treatment. The treated grain was compared with untreated, uninfested source corn. Five 237-ml (½-pint) cartons of treated corn from a bin and five of untreated corn were alternated in the apparatus. About 500 rice weevil adults, 14 days old, were liberated in the depressed release area located in the center of the chamber to scatter over the dispersal plane. The insects were given a 24-hour opportunity to choose from among the cartons of treated and untreated corn. Following the dispersal period, the rice weevils were sifted from the individual cartons for counting.

The grain temperature in all bins was taken at 7-day intervals by inserting a glass thermometer into the center of the grain mass. Samples for residue analyses were taken with the nonpartitioned grain trier.

At the end of the 12-month storage period, additional 3,000-gram samples were probed from each bin. These samples were screened over a 4-mesh screen to remove the kernel bits, insects, frass, and dusts. The screenings were

TABLE 1.—*Average mass temperatures (°C) of insecticide-treated corn during 12 months' storage*

Insecticide	Months of storage											
	1	2	3	4	5	6	7	8	9	10	11	12
Sprays:												
Malathion	26.7	26.6	26.0	25.8	25.9	25.7	25.7	25.5	25.5	25.5	25.3	25.5
Pirimiphos-methyl	26.6	26.0	26.0	26.1	26.2	26.1	25.8	25.8	26.7	26.1	25.6	26.1
Fenitrothion	26.7	26.0	25.9	26.0	25.8	25.7	25.7	25.7	25.7	25.8	25.6	26.1
Chlorpyrifos-methyl	26.6	26.0	25.7	25.8	25.9	25.6	25.6	25.6	25.6	25.5	25.3	25.5
Dusts:												
M+K	26.5	26.0	26.1	26.1	26.2	26.0	26.1	25.6	25.7	25.8	25.8	25.8
Untreated:												
Check	26.7	27.8	32.2	32.3	33.3	34.4	36.1	35.0	34.5	32.8	31.6	31.1

sifted over a No. 25 sieve to separate the insect frass and other dusts from the insects and parts of kernels. The frass and dusts were weighed to estimate the insect damage to the grain. These fine siftings were remixed with the sifted grain and were stored in screen-covered 3.8-liter glass jars for 56 days to observe insect development and emergence.

RESULTS

As there was only one dosage of each formulation, the rates are not shown in the tables. They were as follows: malathion 11.2 p/m, pirimiphos-methyl 8.4 p/m, fenitrothion 8.9 p/m, chlorpyrifos-methyl 6.7 p/m, and malathion in the M+K dust 11.2 p/m.

Grain Temperature and Moisture

Slight elevations in grain temperatures were noted in bins of untreated corn during the latter part of the second month of storage (table 1). Insect activity caused the temperature to rise in all of the untreated bins until the eighth month of storage; thereafter, the temperature in these bins gradually decreased.

All treatments prevented the establishment of damaging infestations in the treated corn and consequently no pronounced elevations in the temperature of the corn were found.

The moisture content of the corn had equilibrated at about 13.2 percent when the treatments were started. A gradual reduction was noted in all treated lots during the 12-month storage (table 2). Because of the insect activity in the untreated corn, the moisture content of this corn remained at about 13.2 percent throughout the test.

Residues

Samples taken 24 hours after treatment revealed that initial deposits of 94.0 percent of the pirimiphos-methyl, 80.4 percent malathion (emulsion), 91.0 percent chlorpyrifos-methyl, 69.7 percent fenitrothion, and 68.8 percent malathion (dust) were present on the corn. The residues found on the corn during the next 12 months are shown in table 3. At 12 months, 38.0 percent of the initial pirimiphos-methyl deposit and 39.0 percent of the initial malathion deposit from the dust formulation remained in comparison to only 23.0 percent of the chlorpyrifos-methyl, 15.6 of the malathion (emulsion), and 12.9 percent of the fenitrothion initial deposits.

TABLE 2.—*Average (percentage) moisture content of insecticide-treated corn during 12 months' storage*

Insecticide	Before treatment	Storage period				
		24 hours	1 mo.	4 mos.	8 mos.	12 mos.
Sprays:						
Malathion	13.1	13.2	12.8	12.4	12.4	11.8
Pirimiphos-methyl	13.2	13.2	12.8	12.4	12.3	11.7
Fenitrothion	13.2	13.1	12.8	12.6	12.1	11.8
Chlorpyrifos-methyl	13.2	13.1	12.7	12.5	12.1	11.8
Dust:						
M+K	13.2	12.6	12.5	12.4	12.0	11.6
Untreated:						
Check	13.2	13.2	13.4	13.3	13.2	13.2

TABLE 3.—*Average residues in parts per million on shelled corn stored in small bins*

Insecticide	Calculated dose	Months of storage 1	2	3	4	5	6	8	9	12
Sprays:										
Malathion	11.2	6.1	5.2	4.0	4.1	3.8	3.2	2.4	2.2	1.4
Pirimiphos-methyl	8.4	6.3	6.7	4.5	4.3	4.0	4.1	4.0	3.4	3.0
Fenitrothion	8.9	4.8	4.2	3.4	2.2	2.1	1.7	1.5	1.1	.8
Chlorpyrifos-methyl	6.7	5.0	4.8	4.0	3.2	2.5	2.3	1.9	1.8	1.4
Dusts:										
M+K[1]	11.2	6.8	6.0	5.8	4.6	5.0	5.3	4.0	3.8	3.0

[1]Malathion residue.

Insect Populations

Insects moved freely and uniformly throughout the different areas of the infestation room. The numbers of live adult insects, predominantly rice weevils and flour beetles that were recovered in the 3,000-gram probe samples taken after 4, 8, and 12 months' storage, indicated the populations within the bins during the storage period (table 4). Large numbers of dead rice weevils, *Tribolium* spp. and *Oryzaephilus* spp., were found in the samples, but few live insects were recovered from the treated corn throughout storage. However, comparatively large numbers were recovered from the check bins.

Insect Emergence

After removal of the live and dead insects from the 3,000-gram samples taken after 12 months, the sifted corn and dusts were recombined and retained for 63 days for counts of the numbers of insects which developed. Few insects emerged from any of the treated samples, but comparatively large populations emerged from the untreated corn, even though it was severely damaged (table 5).

As the corn was screened to remove the insects, the fine dusts and frass were weighed to estimate the amount of damage inflicted by the insects during the 12 months of storage (table 6). Damage to all treated corn was minor, and the pirimiphos-methyl and chlorpyrifos-methyl-treated lots sustained the least damage.

The 3,000-gram samples were then held an additional 120 days for a visual assessment of the infestation and subsequent damage. At that time, differences were more pronounced (table 7). One replicate of pirimiphos-methyl treated corn was infested with lesser gain borers and

TABLE 4.—*Number of live adult insects recovered from 3,000-gram probed samples of insecticide-treated corn during 12 months' storage*[1]

Insecticide	Insects in samples taken after— 4 months	8 months	12 months
Sprays:			
Malathion	3.3	9.0	3.8
Pirimiphos-methyl	1.3	1.3	3.0
Fenitrothion	11.0	17.0	18.3
Chlorpyrifos-methyl	1.0	4.5	4.0
Dust:			
M+K	6.0	5.0	1.5
Untreated:			
Check	353.5	905.8	718.8

[1]Average of four replications.

TABLE 5.—*Number of emerging live adult insects from 3,000-gram samples of insecticide-treated corn after 12 months' storage*[1 2]

Insecticide	Rice weevils	*Tribolium* spp.	*Oryzaephilus* spp.	Others	Total
Sprays:					
Malathion	4.0	13.5	12.3	14.5	44.3
Pirimiphos-methyl	0	5.0	1.5	0	6.5
Fenitrothion	18.3	21.3	14.0	11.8	65.4
Chlorpyrifos-methyl	1.3	6.5	0	0	7.8
Dust:					
M+K	0	1.5	1.0	0	2.5
Untreated:					
Check	251.5	144.0	396.8	107.0	899.3

[1]Samples held for 63 days for emergence at end of 12 months' storage period.

[2]Average of four replications.

TABLE 6.—*Grams of insect frass per 3,000-gram sample of insecticide-treated corn after 12 months' storage*

Insecticide	Average	Range
Sprays:		
Malathion	5.23	3.4- 7.8
Pirimiphos-methyl	1.68	1.3- 2.1
Fenitrothion	6.78	3.8- 10.9
Chlorpyrifos-methyl	1.73	1.3- 2.3
Dust:		
M+K	3.58	2.4- 6.1
Untreated:		
Check	144.45	107.5-167.0

two replicates of the chlorpyrifos-methyl treated corn contained some live flour beetles. Corn treated with malathion, fenitrothion, and the M+K dust showed slight damage by a few insects in most of the samples.

Insect Damage

Assessments of insect damage to the corn after 12 months' storage included the amount of insects' frass in samples (table 6), losses in test weight, percentages of kernels damaged by insects, and kernel weight losses.

The changes in the test weight of the corn are shown in table 8. The application of the M+K dust caused an immediate loss of 3.1

TABLE 7.—*Visible damage by insects developing in samples collected after 12 months' storage*[1]

Insecticide	Damage after 120 days[2] Average	Range
	Rating	*Rating*
Sprays:		
Malathion	1.3	1-2
Pirimiphos-methyl	.3	0-1
Fenitrothion	1.5	1-2
Chlorpyrifos-methyl	.5	0-1
Dusts:		
M+K	.8	0-1
Untreated:		
Check	4.5	4-5

[1]Average of four replications.
[2]Damage rating codes: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

TABLE 8.—*Average test weights (pounds) per bushel of samples of insecticide-treated corn at given intervals during 12 months' storage*

Insecticide	Immediately Before treatment	Immediately After treatment	After 4 mos.	After 8 mos.	After 12 mos.	Loss during storage
Sprays:						
Malathion	57.5	57.5	57.7	57.5	57.3	0.2
Pirimiphos-methyl	57.4	57.5	57.6	57.4	57.4	.1
Fenitrothion	57.5	57.4	57.6	57.4	57.2	.2
Chlorpyrifos-methyl	57.5	57.5	57.7	57.6	57.4	.1
Dust:						
M+K[1]	57.4	54.3	54.7	54.3	54.2	.1
Untreated:						
Check	57.4	57.4	55.7	49.6	42.3	15.1

[1]The initial loss of 3.1 pounds during treatment was caused by the addition of the diatomaceous earth.

pounds per bushel of corn. The adherence of the dust to the corn affected flowability and the settling and nestling qualities of the grain. This resulted in a smaller number of kernels per given volume (about 5 percent loss) and thus reduced the weight per bushel. Little test weight loss was recorded from any of the samples of the treated grain during storage. The untreated corn lost 15 pounds per bushel or about 26 percent of its original weight.

In the untreated corn, damage was heavy with over 62 percent of the kernels showing insect feeding (table 9). Many of the heavily damaged kernels, especially those with extensive feeding, are often broken up and pass through the screens during the removal of insects and dust in the screening process for the insect counts and record of insect frass. Consequently, losses to heavily damaged kernels are sometimes not recorded. In the weighing of the damage to 1,000 kernels from each bin in storage, only 68.2 percent of the original kernel weight remained in the untreated corn. Corn treated with the insecticides lost only 0.97 to 1.59 percent of kernel weight from insect feeding.

Food Selection Studies

Competitive multichoice offerings of samples from the different grain treatments to 14-day-

TABLE 9.—*Percentage of average kernel damage and calculated kernel weight loss in samples of insecticide-treated corn during 12 months' storage*

Insecticide	Kernels damaged in sample—				
	Before treatment	After 4 mos.	After 8 mos.	After 12 mos.	Weight loss
Sprays:					
Malathion	0.28	1.23	1.69	3.39	1.59
Pirimiphos-methyl	.26	1.01	1.42	3.03	.97
Fenitrothion	.24	1.39	1.74	4.56	1.55
Chlorpyrifos-methyl	.24	1.20	1.49	3.16	1.03
Dust:					
M+K	.23	1.07	1.46	3.02	1.38
Untreated:					
Check:	.24	17.28	34.17	62.48	31.84

old rice weevil adults showed that the M+K dust treatment was the only one which affected the acceptability of the corn (table 10). The untreated corn appeared somewhat less acceptable to the rice weevils at the end of the test than at the beginning of the storage, probably because of the heavy damage.

Repellency Tests

In the repellency tests conducted with replicated samples 1, 4, 8, and 12 months after treatment, the M+K dust imparted repellency to the grain to rice weevils, but the degree of repellency was reduced as the storage period approached termination (table 11). None of the other treatments imparted repellency. Grain

TABLE 10.—*Response of rice weevils to insecticide-treated and untreated corn in food selection studies*

Insecticide	Percentage of weevils that entered samples after storage period of—			
	1 month	4 months	8 months	12 months
Sprays:				
Malathion	20.4	17.2	19.1	18.2
Pirimiphos-methyl	17.5	19.2	17.2	20.0
Fenitrothion	18.5	19.4	17.2	16.4
Chlorpyrifos-methyl	16.1	17.7	20.1	19.4
Dust:				
M+K	5.7	6.3	7.1	8.0
Untreated:				
Check	21.9	20.3	19.3	18.0

TABLE 11.—*Percentage of repellency of treated and untreated corn to rice weevil adults*

Insecticide	Repellency after interval of[1] —			
	1 month	4 months	8 months	12 months
Sprays:				
Malathion	2.0	3.6	4.8	−2.3
Pirimiphos-methyl	.4	−3.2	.8	−5.2
Fenitrothion	−2.0	5.9	−3.2	5.9
Chlorpyrifos-methyl	1.9	−2.7	2.0	−4.3
Dusts:				
M+K	48.8	46.6	42.9	35.74
Untreated:				
Check	5.1	−1.9	9.2	11.0

[1]Equation for repellency:

$$100 - \left(T \div \frac{U+T}{2} \times 100\right).$$

U is the number of insects in the untreated, uninfested source corn and T, the number in the treated corn.

from the untreated check bins that was heavily damaged during the last part of the storage seemed somewhat more repellent than untreated and undamaged grain.

Toxicity Studies

In the bioassay tests conducted 1 month after the insecticide application, adult rice weevils, red flour beetles, and lesser grain borers were killed by all treatments. A few adult confused flour beetles survived in the malathion, fenitrothion, and chlorpyrifos-methyl treated samples; however, no progeny were produced.

Table 12 summarizes the results of all exposures made 4, 8, and 12 months after treatment. The M+K dust, pirimiphos-methyl and chlorpyrifos-methyl treated corn gave nearly complete protection against rice weevils for 12 months, but some rice weevil progeny damage occurred in the samples of corn treated with malathion and fenitrothion (table 13). Adult confused flour beetles were tolerant to the killing action of all the treatments except the M+K dust application (table 12); however, few progeny were produced. Damage caused by progeny of this insect occurred in one sample of malathion and two samples of fenitrothion treated corn (table 13).

TABLE 12.—*Adult insect mortality after 21 days' exposure to insecticide-treated corn and subsequent emergence of the F_1 progeny after infestation*[1]

Insecticide	4 months Mortality	4 months Progeny Total	4 months Progeny Dead	8 months Mortality	8 months Progeny Total	8 months Progeny Dead	12 months Mortality	12 months Progeny Total	12 months Progeny Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
	RICE WEEVIL—PROGENY COUNTED 56 DAYS AFTER INFESTATION								
Sprays:									
Malathion	100.0	0	—	98.6	3.0	100.0	88.9	14.5	29.3
Pirimiphos-methyl	100.0	0	—	100.0	1.0	100.0	100.0	14.8	100.0
Fenitrothion	100.0	4.3	94.1	100.0	4.0	93.8	100.0	11.0	63.6
Chlorpyrifos-methyl	100.0	0	—	100.0	1.3	100.0	100.0	2.0	50.0
Dust:									
M+K	100.0	1.5	100.0	100.0	2.0	100.0	100.0	7.0	100.0
Untreated:									
Check	0	653.0	0	0	490.3	1.0	0	472.0	.5
	LESSER GRAIN BORER—PROGENY COUNTED 63 DAYS AFTER INFESTATION								
Sprays:									
Malathion	98.2	0	—	74.0	13.5	64.8	17.6	20.0	25.0
Pirimiphos-methyl	90.2	4.0	100.0	31.5	31.0	32.3	1.5	39.0	28.2
Fenitrothion	95.5	2.0	100.0	31.9	37.0	51.4	13.7	22.0	36.3
Chlorpyrifos-methyl	96.6	0	—	73.3	13.3	69.2	37.5	15.8	44.3
Dusts:									
M+K	100.0	0	—	100.0	11.3	100.0	100.0	0	—
Untreated:									
Check	0	244.3	0	2.0	250.5	0	1.9	266.0	5.1
	RED FLOUR BEETLE—PROGENY COUNTED 63 DAYS AFTER INFESTATION								
Sprays:									
Malathion	79.9	0	—	23.1	6.0	100.0	11.4	10.0	50.0
Pirimiphos-methyl	100.0	0	—	100.0	0	—	99.0	0	—
Fenitrothion	89.8	0	—	27.9	7.0	71.4	16.9	2.0	0
Chlorpyrifos-methyl	100.0	0	—	89.0	0	—	72.6	3.0	100.0
Dusts:									
M+K	100.0	0	—	97.2	0	—	82.0	0	—
Untreated:									
Check	2.0	52.3	0	0	46.8	0	0	41.0	0
	CONFUSED FLOUR BEETLE—PROGENY COUNTED 70 DAYS AFTER INFESTATION								
Sprays:									
Malathion	47.6	0	—	3.4	0	—	1.4	3.0	0
Pirimiphos-methyl	92.8	0	—	41.9	0	—	14.5	0	—
Fenitrothion	74.5	0	—	1.3	8.0	0	2.0	5.3	0
Chlorpyrifos-methyl	43.5	0	—	5.0	0	—	4.5	0	—
Dust:									
M+K	100.0	0	—	100.0	0	—	95.9	0	—
Untreated:									
Check	0	88	0	0	64.3	0	0	78.3	.6

[1]Average of five replications per treatment.

TABLE 13.—*Visible damage by insect progeny in samples of insecticide-treated corn after toxicity tests*

Insecticide	Damage observed 120 days after infestation of samples taken after a storage period of[1] — 4 months	8 months	12 months
	Rating	*Rating*	*Rating*
	RICE WEEVIL		
Sprays:			
Malathion	0	0	2.0
Pirimiphos-methyl	0	0	0
Fenitrothion	0	.2	1.8
Chlorpyrifos-methyl	0	0	0
Dust:			
M+K	0	0	0
Untreated:			
Check	[2]5.0	[2]5.0	[2]5.0
	LESSER GRAIN BORER		
Sprays:			
Malathion	0	1.0	2.0
Pirimiphos-methyl	0	1.2	3.0
Fenitrothion	0	1.2	2.8
Chlorpyrifos-methyl	0	.2	.4
Dust:			
M+K	0	0	0
Untreated:			
Check	5.0	5.0	[2]5.0
	RED FLOUR BEETLE		
Sprays:			
Malathion	0	0	0.4
Pirimiphos-methyl	0	0	0
Fenitrothion	0	.2	.2
Chlorpyrifos-methyl	0	0	0
Dust:			
M+K	0	0	0
Untreated:			
Check	2.0	2.0	2.0
	CONFUSED FLOUR BEETLE		
Sprays:			
Malathion	0	0	0.2
Pirimiphos-methyl	0	0	0
Fenitrothion	0	.2	.4
Chlorpyrifos-methyl	0	0	0
Dust:			
M+K	0	0	0
Untreated:			
Check	2.0	2.0	2.4

[1]Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amounts of insect frass; 5 = large infestation with great amounts of insect frass and destruction of grain.

[2]Reading 90 days after infestation.

The M+K dust and pirimiphos-methyl treatments were effective against the red flour beetle (table 12) and no F_1 progeny were produced. A few F_1 progeny were found in the corn treated with chlorpyrifos-methyl, but they were not able to establish infestations. Infestations were established in some of the corn treated with malathion and fenitrothion (table 13).

All treatments were effective against the lesser grain borer for 4 months, but thereafter only the M+K dust gave excellent protection (table 12). Chlorpyrifos-methyl gave good protection and progeny damage was minimal (table 13). The other treatments were less effective with this species during longer storage.

CONCLUSIONS

Objective assessments were made of the protection provided by four candidate materials applied to corn at selected dosages. All treated lots were given equal opportunity for infestation by mixed populations of stored-grain insects throughout 12 months' storage. Results were consistent between the different replications of each material in all studies undertaken. The following conclusions were drawn:

1. Protectant sprays prepared with pirimiphos-methyl, chlorpyrifos-methyl, and fenitrothion, applied at selected dosages, gave protection equal to or better than the recommended dosage of malathion.

2. The M+K dust gave excellent protection from insect attack, but the addition of the dust reduced the test weight of the corn.

3. Malathion residues degraded more slowly on the corn treated with the dust formulation than on corn treated with the emulsion.

4. The M+K dust treatment repelled rice weevils but the other treatments did not affect the attractiveness of the corn as a food.

5. The pirimiphos-methyl residues on corn degraded more slowly than the residues from the other emulsion sprays.

6. Lesser grain borers were controlled in the toxicity tests with corn from the M+K dust treatment. Little lesser grain borer damage occurred in corn treated with chlorpyrifos-methyl in contrast to considerable damage in corn from the other emulsion treatments.